V.

RESEARCHES IN TELEPHONY.

By Professor Dolbear.

Presented Nov. 13, 1878.

I began my experiments in Telephony in August, 1876, my first attempts being with a Helmholtz interruptor, using forks whose vibrations were 64, 128, and 256 per second respectively. For a receiver a coil of wire about a small rod of iron, as in Page's experiment in 1837, in which he used an automatic interruptor. I also used several forms and sizes of electro-magnets as receivers.

With all of these arrangements the reproduction of the sound was well marked. The next step was to cause the vibrations produced by the voice to make and break the circuit in a manner analogous to that of the vibrating forks. To this end a platinum wire was made fast to the end of an opeidoscope tube having a membrane of stretched rubber over the end. The wire was bent at right angles at the middle of the membrane, and projected about half an inch from it. This wire was coupled in circuit with the instruments mentioned above as receivers, and the tube being placed at the mouth while the tip of the wire on the membrane dipped into mercury, also into water acidulated, some of the sounds were very audible; but it was necessary to make the membrane vibrate with amplitude enough to break completely the circuit, or no sound whatever could be heard. From this I concluded that the difference of resistance interposed by the vibrations was not great enough. I therefore sought for some means to increase the difference, and made for that purpose a small cone of iron, which was soldered to the wire upon the opeidoscope tube, for the reason that, when the cone was plunged into the mercury, a slight motion of the membrane would materially vary the cross-section immersed and consequently the interposed resistance. With this arrangement no better results were obtained, as it was found that the mercury bounded away from the cone when the latter was vibrating. I therefore sought for other means for varying the current strength.

One is necessarily shut up to the two only possible ways of varying the current; namely, varying the resistance, or varying the electromotive force. I had tried the first with no satisfactory results, and then attempted the second.

In the spring of 1864, while a student in the Ohio Wesleyan University at Delaware, Ohio, I was employed to make a large electromagnet and a large permanent magnet for illustrative purposes at the University. While engaged in making these, I devised a magneto-electric telegraph, in which the currents were to be generated by a permanent magnet thrust into a coil or hollow helix; and these currents were to reproduce like motions upon a permanent magnet at the other end of the line. The device was not dissimilar to the one made by Gauss and Weber of Göttingen, in 1833; but I knew nothing of their work at that time.

In 1873 I observed a deflection of a galvanometer needle, when the stem of a vibrating tuning-fork was held upon the face of a thermopile. The tuning-fork used was a rather large one, giving E^b of about 78 vibrations per second; the prongs had been made magnetic for other experiments, and the inductive effects of the movements of these poles upon the face of the pile was also noted. The following is the record from my note-book, and dated Aug. 15, 1873: —

"Noticed the effect of the vibrating fork, which was also a permanent magnet, upon the current, when one face of the pile was heated. If the fork was moved no faster than the galvanometer needle would vibrate, once in about 4 seconds, the needle would be set swinging. If the fork vibrates its natural rate, 78 per second, the needle couldn't move, as the current was changed faster than the needle could move."

This was a *vibratory current in a closed circuit* originated by sound vibrations.

I understood this to be simply a particular case of magnetic induction that was familiar enough to every one who was acquainted with Faraday's work; the former experiment I described at the Portland meeting of the A. A. A. S., in 1873, as I thought it to be new. With this experiment, and my invention of 1864, I was prepared with all that was necessary for the plan for a speaking telephone, which was matured and bears the date of Sept. 20, 1876.

"Let a coil of wire be about the pole of a permanent magnet, and the terminals be attached to a galvanometer; then, when a piece of iron approaches the magnet, a current is induced. Suppose that the wires connect with another coil about a permanent magnet; then the

current will affect a piece of iron in front of the poles in the same way as the first is affected. In this way a telephone may be constructed. By making a sound to vibrate a piece of sheet iron in front of one magnet, the ear applied to the other magnet should hear the kind of sound made at the first."

Within a few days of that time, I began the construction of a pair of such instruments, entrusting them to Mr. A. Stetson, a teacher at Rockland, who came to Tufts College on Saturdays to work in the Physical Laboratory. The first ones attempted were begun with a pair of straight-bar permanent magnets belonging to the College; they were 8 or 9 inches long and about half an inch in diameter. The helix was wound directly upon the magnets, while the vibrating armature was glued to an opeidoscope membrane. The first one made I have now, just as it was used at that time; the membrane was made of sheet rubber, and was two and three-eighth inches in diameter. The iron armature glued to it was an inch and a half long by three quarters of an inch broad, rectangular in outline.

Mr. Stetson was employed to make a pair of instruments, in which no battery was to be used, and both instruments were to be alike. Before they were completed, he stopped coming to the College for several weeks, and they were consequently delayed in a manner that they would not have been if I had thought of the very great value of the invention.

I was extremely busy with my college work and also in getting a book through the press, and couldn't attend to it very well myself. About the first of October, the plan of using an armature of iron glued to a membrane was changed to one where the armature was to cover the entire end of the tube and be screwed to it. This was done for two reasons; one being that the armature could not be brought close to the magnet without its adhering to it, and, second, that the vibrations of the voice-sounds could be easily felt when talking against a large piece of rigid paper or piece of board, from which it was inferred that the vibrations of an iron armature would be sufficient to induce the requisite currents. Mr. Stetson started a pair upon this plan at once, but, as I said before, he failed to complete them, as he did not come to College Hill from about the fourteenth of October till some time in December. Early in December, one evening, I took one of the incomplete telephones and endeavored to measure the resistance through which such an induced current would be manifest by means of a Thomson galvanometer and a set of Resistance Coils, and found I could readily get a deflection with an inserted resistance of fifteen thousand ohms, —

the linear limit of my Rheostat, which I reckoned equal to nine hundred miles of ordinary telegraph wire. Up to this time I had thought of the invention solely in its scientific relations, and was not pursuing that as I ought to, as I knew that Prof. Bell had pre-empted the ground. Indeed, I was waiting for an opportunity to see him to tell him to use the permanent magnet, as every account of his work said he was using a battery; but when the great value of the invention was shown to me, and I learned that Prof. Bell patented his work as soon as possible, I concluded to try to profit by it myself. I therefore began at once upon a pair of instruments to that especial end, but before I had time to complete them I heard that the device had already been patented; so I ceased my hurry upon them. Indeed, I didn't finish them for some weeks. In these instruments the magnets were of half-inch round steel, and the bobbins were taken from some old telegraph instruments that I found at Hall's on Bromfield St., as they just suited my purpose. I have these instruments now, and they are very fair telephones, and will do good work.

I next had a pair made in much better shape, and used them in several public exhibitions during the spring and summer of 1877. Upon these instruments I had a flaring horn mouth-piece. At one time I took them to the railroad between Elm St. station and North Avenue station, attached the terminals to the two lines of rails at either end, and was able to converse over the rails in that way. This was on the seventeenth of July, 1877. In the attempts to improve the telephone a great many hundred experiments have been tried, and among them not a few devices that have since been patented by other parties. Among the first of these was the using of a magnet upon each side of the plate; this was done as early as March, 1877, and that device was exhibited at a public exhibition that I gave of the invention early in April of that year, at Tufts College.

In April, I fixed several sets of magnets and bobbins to act upon one plate. The results were no better than when only a single pair was used. In my instruments made in February the magnets were compound horse-shoe magnets, such as could be bought in the stores; and such an arrangement I have uniformly found to be the best for loudness of sounds.

My next improvement consisted of placing a cushion of felt under the vibrating plate; this has been adopted in the making of telephones, as it prevents the too rapid diffusion of the vibrations from contact, and also acts as a damper to absorb the sympathetic vibrations of the plate.

Next it occurred to me that, if the armature of an ordinary sounder,

or relay, could be made to vibrate by sound-vibrations, the corresponding armature of another like instrument in the circuit should respond to the induced current. The armature of an ordinary sounder was first screwed down pretty near to the poles of the magnet, and then the thread from a common string telephone was tied to it, so that the sounds produced in the string telephone should be conveyed by the string to the armature, and thus make it to vibrate. This arrangement was coupled up in electric circuit with a telephone of ordinary pattern, and tried between two distant rooms in a building, with success. Afterwards two like sounders were thus coupled up, and talking was carried on over a circuit nearly half a mile long, using only the sounders with the thread telephone tied to each. The sounders had a resistance of only two or three ohms apiece. Then two relays were tried in like manner, each relay having nearly a hundred ohms resistance, with better results than before. At one time the thread telephone attachment was dispensed with, and the vocal sounds were produced in a small tube held immediately in front of the relay armatures both at sending and receiving instruments. In this way it was easy to hear musical sounds, such as a tune sung; and sentences, if at all familiar, were recognized without much difficulty. But this was of course working under a great disadvantage. I therefore devised a mouth-piece for the armature, and afterwards changed the form of the armature itself, so that it would be adapted to both functions, — that of an ordinary sounder and of a speaking telephone. With such an instrument as I exhibit here, I have worked successfully over the line between Milford, N. H., and Boston, — a distance of fifty miles.

From the first I had interpreted the action of the telephone to be due solely to the ordinary vibrations of the plate being performed in a magnetic field, and varying that field of magnetism. When an ordinary tuning-fork is struck, its vibrations may not only be heard but felt, and also seen; but directly the amplitude decreases, so that it cannot be seen to vibrate, but it can be both felt and heard: but long after it cannot be felt it may still be heard. But no one is at liberty to say that, because the sound only can be heard, the vibrations of the fork differ in any thing than amplitude from those at first seen; and it is admitted generally that such vibrations would be competent to produce such sonorous results as are observed. Nevertheless, there have been several investigators who have stated it as their opinion that the sounds of the telephone were due to some new kind of molecular motion, which was different from an ordinary sound-vibration. To test this view, I constructed a telephone having a mem-

brane of paper carrying a small electro-magnet, with its poles facing the poles of the large inducing magnet. As this has its polarity determined by induction, and the strength of it varying with the distance apart of these facing poles, it is evident that any articulate results obtained under these conditions must be due to the ordinary vibrations to and fro of the disk and magnet upon it. The results with this arrangement were excellent; the articulation was not only good, but it was as loud as in any telephone now in the market. Especially good was it when the electro-magnet was separated from the large magnet by a rather thin piece of rubber, allowing of motion in a longitudinal direction, but not in any other. This I take to be demonstrative evidence that the explanation given above of the telephonic action is true. Diaphragms of other materials were tried, such as wood, zinc, brass, mica, and so on, — a great number. All will work; and paper was found to give the best results, probably because it has rigidity and elasticity enough, while the mass is small, and hence more easily moved by aerial vibrations.

At one time, early in October, it occurred to me to try for a receiver the iron pole of one of the permanent magnets, with its bobbin on of course. That is to say, the permanent magnet was removed, the other conditions remaining as before. With this I was able both to send and receive. Then the iron core was removed, and in its place an ordinary wood-screw an inch and a quarter long was put through the bobbin and screwed into a piece of board three or four inches square, the head of the screw towards the plate. With this arrangement I was still able to receive or send, using the circuit between the College and my house, nearly half a mile long. Now every wood-screw is made slightly magnetic by the process of making the screw, but most wood-screws have but a slight polarity; that used in this experiment was only sufficient to move slightly three or four iron filing bits. Again, experiments were tried with magnets of various forms, — magnets with chambered poles, with poles cut radially, with poles bent at right angles, with wire of various sizes, from No. 22 to No. 37, with the result that No. 28 or 30 seemed preferable for nearly every purpose. The finer wire not only offers so much greater resistance, but in the summer-time it is liable to be injured by lightning. I have had several fine-wire telephones that were injured by the induced current from a flash of lightning a considerable distance away. My line runs for thirty or forty rods under the Somerville fire-alarm wires, and hence would be affected by the inductive action upon them; but between the college building and my house, there is

constantly a current in one way down the hill, and the sputtering of the telephone is sometimes so great, when every thing is quiet out of doors, as to attract attention anywhere in the room. I have several times observed the effect of a thunder-storm upon the line. Generally it happens that before the shower there is nothing to be heard, even though the lightning is only three or four miles away; but while the shower is overhead, the discharges are sometimes so loud from the telephone as to be heard upstairs in my house. And after the shower has passed a long way off, so far that the thunder cannot be heard at all, every flash has a response in my telephone.

A close wound spiral of steel wire was made fast by one end to the middle of the vibrating plate, and the other end to a post seven or eight inches back of it. Within this helix a permanent magnet was so placed as not to touch the coil in any place. It was reasoned that this arrangement should also give sonorous results, as the vibrations of the plate would move the spirals of the coil to and fro across the magnetic field, and thus give rise to corresponding currents in the circuit. This was found to be true; but the results were unsatisfactory, and nothing articulate was heard from it, though some other sounds were. This was also tried by incorporating a battery in the circuit, but with no different results.

A great many experiments were also tried with the view of finding whether the passage of a sound-vibration through an electric conductor would in any way affect the current, to break it up into corresponding pulsations. To this end, batteries of varying elements and strength were coupled to my line, and vibrations set up in the line-wire in various ways, such as by striking, by drawing a resined bow across it, by tying the string telephone to it and making sounds of varying pitch: in none of these was there any observed effects.

Another variation in this experiment was to let a person take the two terminals in a circuit including a battery and a receiving telephone, and, while thus being a part of the circuit, singing and talking in the endeavor to discover if such agitation from sounds as can plainly be felt by one would produce any undulations in the circuit. No such effects were noted.

Three telephones were included in one circuit; two of them close together, the third at a distance. Sounds were produced in the two adjacent ones. It was thought to be possible that the electric waves might neutralize each other if they were sent in opposite directions, if the two had the same intensity, thus furnishing a means of measuring the intensity of sounds; but no such interfering results were noticed.

Nevertheless, it would appear to be theoretically true that such interference should take place under appropriate conditions.

Very many other changes were rung upon the conditions for getting articulate sounds, such as enlarging the bobbins, placing them on both sides of the plate: in one case one was made for a core three inches in diameter, and was used as a tube through which to speak. In another case the bobbin was wound about a pint cup, and a large compound magnet weighing about twenty pounds was placed with one pole close to the bottom of the cup. This made a fair speaking telephone, both as sender and receiver.

Telephones with oval diaphragms, square diaphragms very small and very large, a foot or more in diameter, were made; diaphragm fastened to large resonant surfaces, fastened to the edge, to the middle, to both edge and middle, with magnet fastened to one edge of diaphragm, and the free end of the magnet opposite the middle of it, and so on, — all of these except the largest making good speaking telephones; and these largest when mounted concentrically, leaving a free edge five or six inches all round, make excellent *calls*, as they may be struck with a billet of wood, which starts a current that can be felt in an ordinary receiving telephone, and heard plainly thirty or forty feet away from one. A good many forms of calls were invented, one of them being the so-called "Devil's Fiddle:" a catgut string fastened to the middle of the disk is pulled through a bit of leather with resin on it. The sound of such a device is familiar to every one. I have heard it from a receiving telephone in another room, with the door closed between. Also a tuning-fork call, in which a rather large tuning-fork is made to vibrate and then held so that the vibrations of one leg strike against the telephone plate. This was used as early as January, 1877. Another call consists of a hammer resting lightly upon the plate of the telephone, which will be thrown over by a strong call, and thus ring a bell, or set off an alarm. This can be done with the voice. To measure the amplitude of vibration of such a telephone plate, I had one mounted with a system of levers, one of them carrying a small mirror that reflected a beam of light across the room, when I got a displacement of as much as two feet for some sounds.

So far the experiments have been with the magneto-telephone, where the principle depends upon the varying electro-motive force originating in a magnetic field. But I turned my attention to the other method of varying the current, — namely, by varying the resistance, — and accomplished it in several ways.

First, by making a single battery-cell a sender. If a cell be coupled

up with an ordinary receiver, and one strike with a pencil or snap with thumb and finger one of the elements, the snap will be heard at the telephone. Also if a tuning-fork be held while vibrating upon one of the elements, the sound will be plainly heard. I constructed a single cell of copper-zinc with soldered terminals, the metals being separated by a small piece of rubber tube bent so as to make a cell to hold a dilute solution of sulphuric acid: the metals were about six inches square. With this alone as a sender, when coupled with an ordinary receiver, all sorts of sounds were transmitted, tuning-forks, singing and talking. This was then reduced in size to about that of a watch; the articulation was good, but it has never been very loud. It is better when the tank is filled with water, and a battery current of five or six elements inserted in the circuit.

Second, the Reiss transmitter was modified into the form exhibited, making the plate one terminal and the other a needle-point which could be nicely adjusted by a screw. With this device in a circuit with a battery of any sort, very strong sounds would make and break the circuit, and reproduce the pitch of the sound with great loudness. When the talking was gentle the articulation was very good: one was able to make out every word spoken. When a drop of water was placed between the plate and point, and a weak battery was used, the articulation was excellent; but when a great resistance would permit the use of a strong battery, so as to get a spark of considerable electro-motive force, it became possible to speak and be heard at some distance from the receiving telephone. During a trial of this instrument between Boston and New York last winter, ordinary talking in Boston was heard distinctly in New York, by one who was ten feet distant from the receiving instrument there.

At this time a battery of 100, 125, and 150 gravity cells were used, the best results being obtained with the largest battery. The explanation doubtless is that the air acts as the variable resistant, the vibrations of the plate interposing a greater and less distance between it and the point, the electro-motive force being sufficient at all times to bridge the space. This is the more probable as I have found with the same instrument, and with a greater separation of the plate from the point. If a source of so-called static electricity, as with a Holtz machine, be employed in place of a battery, talking is plainly heard, as I have repeatedly verified over my line.

In place of the point, surfaces of variable dimensions, of various materials, and under many conditions, were tried; surfaces of iron, lead, copper, silver, carbon, in sizes varying from a point up to more than

an inch square, and being in direct contact, or separated by water acidulated; solutions of various sorts, such as nitrate of silver, sulphate of copper, and so on, — all of them being available for the purpose, all of them enabling one to talk and be understood, when an ordinary telephone was used as a receiver. Still further modifications were tried, in which a short wire made fast to the middle of the vibrating plate was covered with a thin coat of wax, except the square end; this placed opposite to another end of wire, and both incased in a small rubber tube filled with mercury. Thus the approach and recession of the points caused by the vibrations of the plate would increase and decrease the resistance in the mercury, while the latter was prevented from bounding away by the pressure of the tube.

In another, a strip of tin was soldered to the plate and bent at right angles so as to project outwards, and the end cut to a point with about ninety degrees included angle; this point rested upon another similar one by light contact, and the current was varied by the amount of surface in contact. The surfaces were also amalgamated and then tried.

Pieces of wood were also screwed to the plate, and then it was saturated with water, with acids, with metallic salts, and with precipitated silver; and in all these ways it was found possible to vary the current sufficient to reproduce sounds, and with almost all of them words were reproduced; that is to say, they were speaking telephones.

All of the above work was done previous to January 1, 1878.

Since then, the chief work has been done with the modification of the transmitter, in which the plate vibrated directly against a point; and the results have been of such a character that I have given a name to the special form, calling it an Electrophone, — a name which I think to be more appropriate even for the common telephone than the name it bears, inasmuch as it is a real conversion of electric energy into sound-vibrations that is effected.

A series of experiments was undertaken to determine if possible the best size for such an instrument, the thickness of the plate, battery power needed, and so on; and to this end I had made an instrument which would admit of the use of a plate varying in size from an inch or less, up to one three inches and a quarter in diameter. I also had a micrometer screw attachment, by which the advancement or recession to the ten thousandth of an inch could be made. Then plates of iron, steel, copper, brass, zinc, lead, tin, plumbago, and graphite were tried, each of a differing size and thickness. With several of these some most excellent results were obtained; for instance, with a plate about

two inches in diameter and one fiftieth of an inch thick, one was able to make himself plainly heard, the articulation being unmistakable anywhere in a room sixteen feet square, while persons thirty or forty feet away would know that one was talking: this over a line about half a mile long and ten gravity cells in circuit. With a stick of graphite the results were about the same. In this case the plate touched upon the slightly rounded surface of a stick half an inch square. Of course singing and strong vocal sounds could be heard very much further: they have been heard fifty feet away from the house by persons in passing carriages. The difficulty has been, and yet remains, to maintain the right pressure of contact. If it be a little too great, the talking sinks to the delicacy of the ordinary telephone; if it be too little, it breaks up so as to give but little except the pitch of the voice; and with the micrometer screw it was not possible to do any better than with an ordinary one. If some device can be invented to keep that uniform, the whole problem of the loud-sounding telephone is solved. A mechanical fixture is all that is needed.

Of all the contrivances tried, the simplest in every way is the following sender: An ordinary tin fruit-can, with one end removed, had one terminal from a battery soldered to it; the other terminal held in the hand so that the circuit was complete when the end of a finger was pressed against the bottom of the can. If, now, one shall talk into the open end of the can, the vibrations of the bottom are sufficient to vary the resistance there enough to render it audible in any ordinary telephone. The resistance of the hand is very great, — 2000 or 3000 ohms; this may be lessened somewhat by wetting the hand, and this improves the effect. In like manner, one may fasten the second terminal of a battery to a stick of gas-carbon, two or three inches long, and, holding the tip of it at an acute angle with the bottom of the can, make himself understood by talking into it.

Most of these investigations have been mechanically carried out by Mr. H. C. Buck, to whose skill and ingenuity I am under many obligations; I have also received considerable assistance of like sort from Mr. W. L. Hooper. To both of them I would express my gratitude for their interest and fidelity.

It was remarked upon a previous page, that one is limited to but two methods in the making of a speaking telephone. This will become evident at once upon the consideration of Ohms's law. All forms of electric telephones depend for their action upon variable electric currents, and hence must conform to the general law of currents. This law is, that the current varies as the electro-motive force

divided by the resistance, and, where proper units are taken, it may be represented thus: —

$C = \frac{E}{R}$, where C is the current, E the electro-motive force, and R the resistance in the circuit. Now electro-motive force depends upon the origin of the electricity. When batteries are used as the source of electricity, the electro-motive force may be modified by coupling cells in series or sets; but if a single cell be used, its electro-motive force is a constant quantity which depends upon the chemical relations of the substances employed. To modify electro-motive force from batteries is entirely impracticable. Not so, however, the electricity derived from magneto-electric machines. Here the velocity of the armature modifies the electro-motive force. The mechanical motion of an armature in a magnetic field re-acts upon the magnet in such a way as to develop a current with electro-motive force proportional to its velocity; the essential thing being the motion of an inductive substance like iron or steel. Seeing that a piece of iron may be made to move rapidly by sound-vibrations, it is plain that such vibrations in a magnetic field will originate currents of electricity with a great electro-motive force; for the rapidity of the vibration of the plate for ordinary speech will be for a man's voice in the neighborhood of 125 per second for the fundamental sound, to say nothing of the overtones. Professor Bell started with the right principle, and, however faulty his first instrument was, it involved the generic idea, as the subsequent development so fully corroborates. Now there are two distinct methods by which the vibratory currents may be set up; namely, by electro-magnets and by permanent magnets. With the first, the action of the armature in the origination of the currents is part of the time to send a wave in the same direction as the current already in the line, and a part of the time to send one in the opposite direction; in other words, it will alternately increase and decrease the current on the line, and this not only by its inductive action upon the magnet, but by its inductive action upon the current circulating in the bobbin, whereas with the permanent magnet there is the inductive action of the armature upon the magnet and coils, while the only electricity in the circuit originates in the coils. The former method originated with Professor Bell, the latter with myself. Some there are who think the two to be identical. I think they hardly can be identical; for in the case of an electro-magnet, when induction is thus utilized, there is not only magnetic induction upon the magnetic core, but there is also electric induction, — that is, induc-

tion upon the current within the coils, — whereas with permanent magnets there is only the first magnetic induction.

Improvements in this direction can hardly be expected, further than to utilize fully the currents which we already get; and these, I am sure, are not fully utilized. For it is not an uncommon experience with my instruments, that the vibrations are strong enough to be very perceptible by the hand upon the instrument; and thus it appears to be like a tuning-fork held in the hand: when struck, the sound is not given out to the air, but is smothered as it were in the hand; but, unlike the fork, it will not be perceptibly louder when placed upon a large resonant surface. It is not improbable that much of this spent energy manifests itself as heat in the plate; but I have not yet investigated this.

There is no third method of varying these primal conditions. These two methods cover the ground of varying the current by means of a change in the electro-motive force.

With the other term, resistance, the case is very different. A change in resistance may be effected by lengthening the conductor, by changing its cross section, by interposing various substances having different conductivities, by varying the density of a loose-grained conductor, and in other ways, each one of the methods mentioned being capable of application in very many different ways. Hence, telephones constructed upon the plan of varying the resistance have been invented in great variety, and by many different persons. Historically, Page, of Salem, stands first; his automatic interruptor being still employed for many purposes, and, when used as he used it in connection with an electro-magnet as a receiver, it was a genuine telephone. This was in 1837. Next, Reiss, of Germany, varied the resistance by platinum terminals when contact pressure was variable; this was in 1861. It would seem that if Reiss had tried an ordinary relay, or some such instrument for a receiver, in place of the one which he did use, he would have had then a good speaking telephone. What was lacking then, was an armature to his receiving magnet. Gray, of Chicago, in February, 1876, used water for the same purpose. In August, same year, I varied the cross section in mercury with the iron cone. In January, 1877, Edison adopted carbon in the form of lamp-black between a vibrating plate and a stiff backing. In December, 1877, I varied the contact pressure between the battery elements, and still later Hughes used free carbon saturated with mercury, and called his instrument a Microphone. The so-called microphone does not differ in any essential thing from the other telephones which have been in use for a good while. The name microphone

is a misnomer, for it does not magnify weak sounds; it simply reproduces them close to the ear. When it is said that a fly can be heard to walk, the function of distance is left out of the account. One cannot hear a fly walk at the distance of three or four feet; but if one can get a fly to walk upon his ear, or upon a plate, like a telephone plate held at his ear, he will find that he can hear the fly walk; and the only reason he doesn't hear it walk under ordinary circumstances is because the fly is too distant. One cannot hear a man walk a mile away, but a telephone will enable him to hear him walk; but one ought not to say that the sound is magnified. The function of a telescope is to make distant objects appear to be nearer; the function of a microscope to make minute objects appear larger. Under no circumstances can a microphone make a walking fly to be heard by one holding a telephone at arm's length from his ear; its function is, therefore, to reproduce distant sounds close to the ear, and it is therefore simply a telephone. Neither does its action require us to modify in the least the general statements concerning sound-vibrations in a body. Whenever there are two surfaces in contact, and one of them is subject to sound-vibrations, the pressure at the two surfaces must vary with the phase of the vibration, and a current of electricity must vary with such pressure. This is strictly in accordance with Ohms's law, and with experience.

If one may borrow from Natural History a terminology applicable to these cases, it may be said that there are two genera of telephones, — the electro-motive and the variable-resistant. These two differ from each other in every essential particular. Of the first there are two species; the electro-magnetic, and the magneto-electric. Of the second there are very many species already, and it is evident that there may be many more.

The synoptical table appended shows at a glance the relations specified above: —

	Genera.	Species.			
Sound-vibrations acting under such mechanical conditions as to modify an electric current by varying the	Electro-Motive Force.	*Permanent Magnets,*	varying a current already on the line	DOLBEAR, Aug.,	1873
		Electro Magnets,	varying a current already on the line	BELL, Spring,	1876
		Permanent Magnets,	originating the only current on the line	DOLBEAR, Sept.,	1876
	Resistance.	*Automatically*	. . . .	PAGE,	1837
		Platinum Contact,	varying pressure . . .	REISS,	1861
		Water,	" space	GRAY, Feb.,	1876
		Iron Cone in Mercury,	" cross-section .	DOLBEAR, Aug.,	1876
		Carbon,	" pressure . . .	EDISON, Jan.,	1877
		Battery Elements,	" " . . .	DOLBEAR, Dec.,	1877
		Carbon-Microphone,	" " . . .	HUGHES, Spring,	1878

Thus it is seen that the two different methods of producing speaking telephones are as unlike each other as a battery is unlike a magneto-electric machine, which, though they have the same function, — namely, to produce electricity, — there is nothing else that is common They may be compared for efficiency, not for involved principles.

Suggested Uses.

I see no reason why the variability of conductivity due to prèssure, as in the case of carbon is so marked, might not be used in many places where now are such instruments as thermometers and barometers. Thus the expansion and contraction of an ordinary copper rod, or, better still perhaps, a thin copper tube, might be made to act upon a piece of carbon in circuit with a constant battery, and the galvanometer needle would constantly indicate the temperature if properly callibrated.

In like manner, the varying pressure of the atmosphere could be made to be much more apparent than now. Perhaps a wind-gauge would also be possible. Especially would it be possible to measure the depth of water by its pressure upon a carbon disk when sunk into the water. Here it would be necessary to have a double-line wire through which the circuit could be maintained during the whole time of the descent; that is to say, the length of wire in the circuit would need to be constant. If the temperature of the water be known, as it generally is, the depth would be easily read off from the galvanometer.